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Human Factors in Cabin Safety

Extensive cabin evacuation trials point to the need for further investigation into the considerations that can influence human survival in an aircraft emergency

by

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Aircraft accidents may be classified into:

- those in which no passengers or crew survive, referred to as fatal or non-survivable.
- those in which all of the passengers and crew survive, referred to as non-fatal or survivable.
- those in which some of the passengers and/or crew survive, referred to as fatal survivable, or technically survivable.

Although, over the last decade the accident rate has reduced in all three categories, statistics from the Civil Aviation Authority (CAA) World Airline Accident Summary show that since 1960 there has been no clear trend of improvement in the percentage of passengers who survive accidents. The data from the non-survivable accidents may be removed, on the basis that in these accidents no increase in safety provision would enable those on board to survive since in these accidents everyone is killed on impact. When the statistics for survivable accidents and fatal survivable accidents (90 percent of all accidents are survivable by some or all of the crew) are examined, it can be shown that although there is greater variability (from year to year), the percentage of fatalities for the last few years was similar to the percentage in the early sixties.

Thus, when the statistics regarding aircraft emergencies are examined, what is of grave concern is the fact that over the last two decades, although the accident rate has reduced, the actual number who survive an accident has not. Recently, a number of steps have been taken to improve this situation. These have included the introduction of fire blocking materials, floor proximity lighting, smoke detectors and additional access at the overwing exits. However, attention has also begun to be focused on the behavior of passengers in accident situations. It is hoped that if there was a better understanding of behavior, in conditions which are for many people highly stressful and disorientating, additional steps could be taken to improve the probability of the successful evacuation of all passengers from the aircraft.

Before any British aircraft is type certified, the manufacturers are required by the regulatory authorities to perform an evacuation. This is done in order to demonstrate that all of the passengers can egress from the aircraft through half of the available exits in less than 90 seconds. In these evacuation demonstrations, attempts are made to make the environmental conditions as realistic as possible — in that they take place in darkness with only the aircraft emergency lighting system for illumination, carry-on baggage, pillows and blankets are strewn in the aisles and three dolls simulating children must be carried by passengers. In these demonstrations, the passengers evacuate the aircraft in a rapid, although essentially orderly manner. This situation should, and in fact, has often been reported in actual emergency evacuations, for example in the evacuation of a British Airways 747 at Los Angeles in February 1987. This evacuation was initiated as a result of a bomb scare.

There are, however, other reports of accidents in which the orderly process was not adhered to, and confusion in the cabin resulted. This confusion has led to reports of blockages in the aisles and at the exits, which has been associated with the consequent loss of life. An example of this was the accident which occurred in Manchester, United Kingdom, in 1985, when 54 people died as a result of a fire which developed, and entered the cabin during an aborted takeoff following an uncontained engine failure.

It could be suggested that one of the primary reasons for the differences in behavior in the two situations rests with the individual motivation of the passengers, i.e., in an evacuation demonstration and in some accidents, all of the passengers assume that the objective is to get everyone out of the aircraft as quickly as possible, and they therefore all work collaboratively. In other emergencies, however, the motivation of individual passengers may be very different, especially in the presence of smoke and fire. In a situation where an immediate threat to life is perceived, rather than all passengers being motivated to help each other, the main objective that will govern their behavior will be survival for themselves, and in some instances, members of their family. In this situation, people do not work collaboratively and the evacuation can become very disorganized.

From the reports of a number of accidents it has been possible to build up a picture of the exits typically used by passengers who survive an emergency where there is smoke and fire.

From this it is known:

- that some passengers exit by their nearest door, as would be expected.
- that other passengers do not exit by their nearest available door but travel for considerable distances along the cabin; e.g. extreme cases of back to front. Why, and in what circumstances do they choose to do this?
- that other passengers, apparently near exits, do not survive. Do they panic and freeze, give up, get crushed by other people or have their seat backs pushed onto them?
- that blockages can occur in the aisles and at exits in some accidents. This does not occur in evacuation demonstrations for certifications.

Thus, there are obviously a great many questions which remain unanswered about the behavior of people in emergencies.

Some work has been conducted on the range of factors that can influence whether or not all of the passengers are able to evacuate an aircraft in an emergency. Snow, et al,[1] in 1970, broadly categorized these factors into four groups: configurational, procedural, environmental and behavioral.

- Configurational — the standard features of the aircraft cabin which may influence access to exits and hence evacuation flow rates, e.g., seating density, number and location of exits.
- Procedural — this includes the experience and training of the crew and other rescue personnel, e.g., fire crew, which can influence the evacuation procedures.
- Environmental — these are the features of the cabin and external conditions which influence the survivability and evacuation time, e.g., heat and toxic smoke in the cabin, light and weather conditions externally.
- Behavioral — these include the psychological, biological and cultural attributes of individual passengers which influence their behavior as individuals and as members of a group, e.g., sex, age, prior knowledge and experience, fitness, physical and mental health, etc.

Cranfield Experimental Program

In response to a request from the U.K. CAA, the Applied Psychology Unit at Cranfield has initiated an experimental program to investigate the influence of cabin configuration on the behavior of passengers, specifically in situations where the evacuation process has become disorderly. The research aimed to investigate the effects on passenger behavior and flow rates during emergency evacuations, of the width of the entrance to the vestibule area leading to the main (Type I) exits, and the configuration of the seat rows which form the access to the overwing (Type III) exits.

In any research program which investigates accident or emergency behavior (from either aircraft, motor vehicles, fires in buildings, etc.), the researchers are faced with a dilemma: how to introduce sufficient realism into the experimental program, while at the same time not putting people at serious physical and, perhaps, mental risk. This trade-off between safety and realism was a challenge at the design stage of the investigation.

To determine the experimental design, consideration was given to the information already available regarding behavior in emergencies.

Information from the literature[2], regarding human behavior in accidents, indicates that where there is a serious threat to life, and only a limited opportunity for escape, not only is everyone very frightened but it is human nature for individuals to compete with each other in order to survive.

The behavior observed in the accident which occurred at Manchester in 1985, and in other accidents in the U.K., including the fire at the Bradford City football stadium and the Zeebrugge ferry disaster, support this theory, e.g., in the Zeebrugge disaster some adults pulled children off life rafts in order to survive.

For both ethical and practical reasons it is not possible to put volunteers into a situation of fear and threat for the purpose of research, e.g., it would not be acceptable to take a group of volunteers on a flight and then tell them that an emergency has occurred, and video their behavior. However, a technique used in laboratory work in behavioral science is to offer an incentive payment to subjects. This is done in an attempt to influence the motivation and performance of individuals either individually or in groups.

In the Cranfield experimental program, an incentive payment system was used in order to introduce an element of competition. A series of evacuation exercises were performed in which an incentive payment was given to the first half of the subjects to leave the aircraft. Volunteers recruited from the public were paid £10 attendance fee to perform four emergency evacuations from an aircraft, with a £5 bonus paid to the first half of the volunteers to exit the aircraft on each evacuation. Using this technique, the influence of five different seating configurations at the overwing exit and five configurations at the galley vestibule on evacuation behavior and rate have been evaluated.

The following configurations have been assessed:

(a) Galley entrance (Fig. 1)
- (1) a width between the galley units of 20 inches.
- (2) a width between the galley units of 24 inches (as is currently found on many aircraft).
- (3) a width between the galley units of 30 inches.
- (4) a width between the galley units of 36 inches.
- (5) port galley totally removed.

(b) Overwing seating (Fig. 2)
- (1) U.K. CAA minimum standard, prior to Air worthiness Notice 79, with a seat pitch of 29 inches.

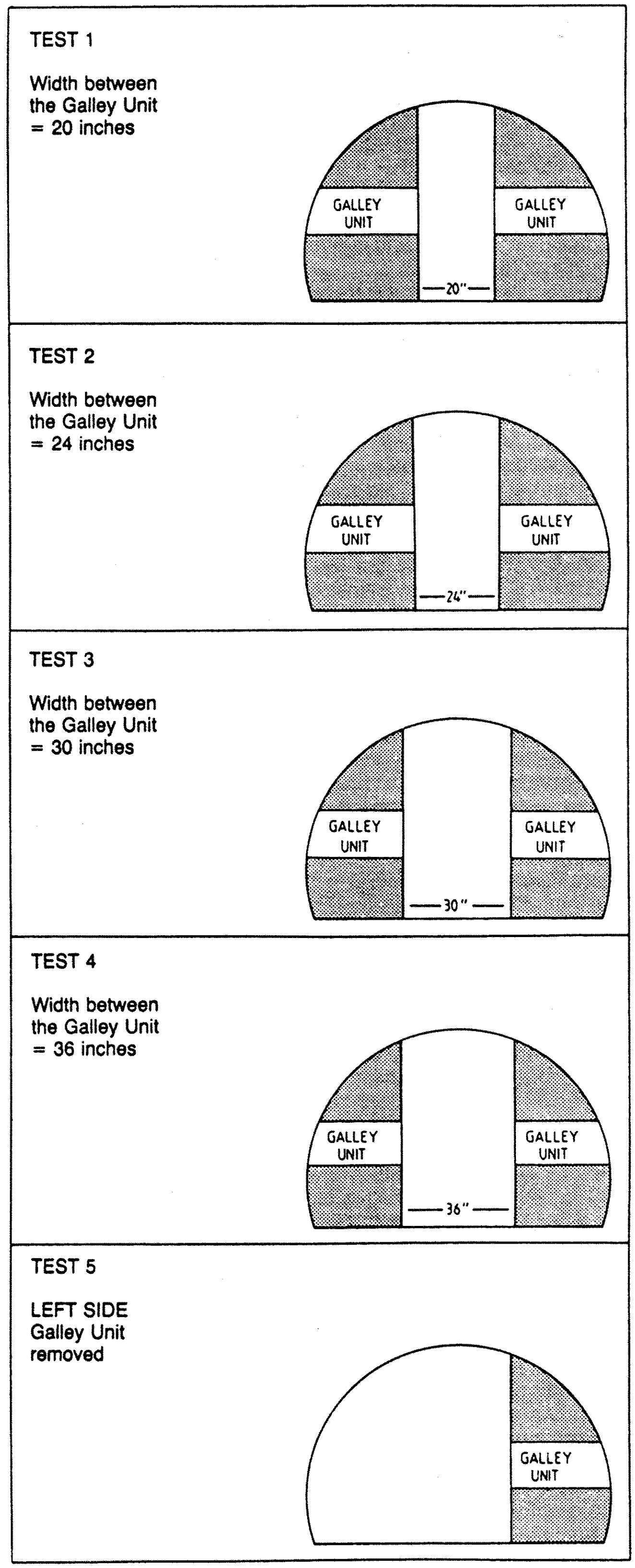

Figure 1

(2) CAA standard, specified in Airworthiness Notice 79, with a seat pitch of 39 inches.
(3) a configuration in which the seat pitch was 44 inches.
(4) CAA alternative standard in Airworthiness Notice 79, in which the seat row located in line with the exit has the outboard seat removed. The seat fore and aft will be at normal seat pitch of 32 inches.
(5) a configuration in which the seat pitch was 51 inches.

The seat backs on the rows fore and aft of the exit were secured in an upright position for conditions (b), (2) — (5).

The initial program of experimental trials involved 20 days of testing. On each test day, approximately 55 volunteers from the public participated.

Each group of volunteers performed the four evacuations through four different test configurations (two through the galley vestibule and Type I exits and two through the overwing exit).

A counterbalanced design (latin square) was employed in this evaluation in which the ten configurations were tested on eight occasions.

Prior to each evacuation, the volunteers were not given any information regarding the cabin configuration or given an explanation of what exits to use.

Regarding safety, only volunteers who claimed to be reasonably fit and were between the ages of 20-50 were recruited. On arrival all volunteers were given a medial examination. They were asked to complete a questionnaire indicating that they had (a) fully understood the purpose of the trials, (b) that the medical information which they had supplied was correct and that (c) they were satisfied with the insurance coverage. A doctor and the airfield fire service were present at all times. A system of alarms was introduced to stop any trial should a real emergency occur.

To introduce as much realism as possible, the trials took place aboard a Trident aircraft parked on the airfield at Cranfield. On boarding the aircraft, volunteers were met by members of the research team trained and dressed as cabin staff. Following a standard pre-flight briefing, volunteers heard taped noise of the engine start up, taxi down the runway and finally the sound of an aborted takeoff, followed by the voice of the captain telling them to undo their seat belts and get out.

The exits to be used were opened by the cabin staff, or members of the research team. This was to ensure the evacuation times were not influenced by the variable time taken for passengers to open doors[3].

Ramps were mounted at the doors for passengers to walk onto. This ensured that volunteers did not hesitate be-

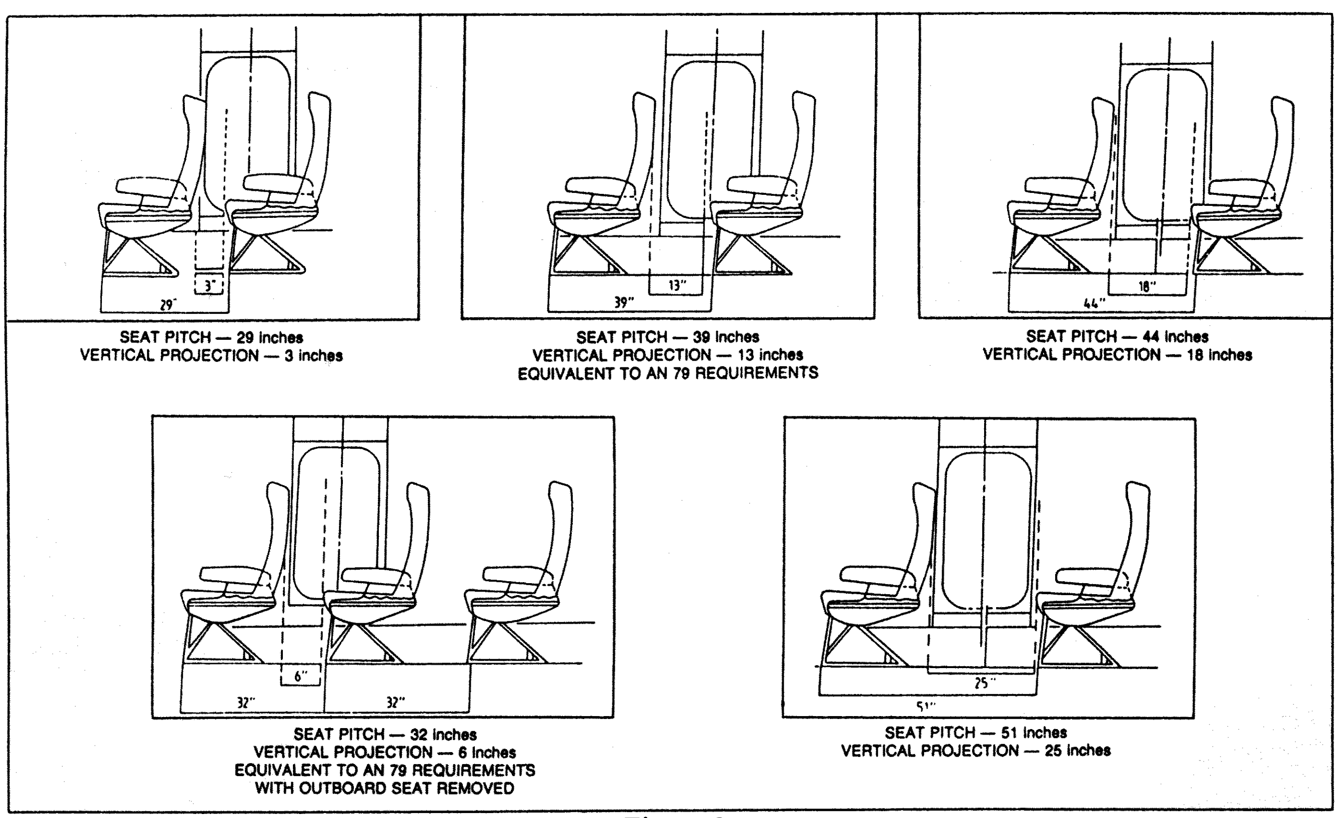

Figure 2

fore leaving the aircraft. It also reduced the potential risk of injury which may have been sustained if the chutes had been employed, thus eliminating another possible compounding variable. The behavior and evacuation times of the volunteers were recorded using video cameras (with time bases) mounted inside and around the exits from the cabin.

Questionnaires were completed by all of the volunteers after each evacuation to obtain information about the route they took to exit, to obtain a rating of the difficulty of the evacuation, and the factors which impeded their exit.

At the conclusion of 20 days of experimental trials, 79 evacuations had been performed (deteriorating weather conditions made it hazardous to initiate the final evacuation on one test day). On three occasions, it became necessary to halt the evacuation after it had been initiated because the number of volunteers attempting to pass through an exit led to a situation in which individuals were stuck in the aperture, and the safety officer considered it dangerous to continue. A fourth evacuation was halted when a volunteer fell into the galley vestibule area, after being pushed through the galley restriction, and was at risk of being trampled upon by others in their attempts to evacuate.

The use of the emergency alarm procedure on all occasions worked most effectively, and no serious injuries were sustained by volunteers in the course of the trials. Over 1,100 subjects took part, of which 68.4 percent were male and 31.6 percent female. The mean age of the participants was 29.1 years (standard deviation was 8.2 years).

Owing to the sensitive nature of the results from these trials within the industry, and the fact that the statistical treatment of the data is incomplete, it is not possible to report the finding regarding the optimum configurations. Nevertheless, the preliminary results demonstrate that the technique of introducing incentive payments to evaluate design options or safety procedures for use in emergency situations, has the potential to supply the statistical data required. Using this technique it is possible to determine which of the alternative cabin configurations tested would enable passengers to egress from the aircraft with the greatest speed in an emergency. The technique has an additional advantage, in that it can also enable important information about many other aspects of passenger behavior in emergencies, to be obtained.

The video and questionnaire data from the trials are providing an insight into findings, which have been reported from accidents, such as why survivors frequently report that there was no noise in the cabin; how some passengers manage to by-pass others and come from the back to the front of the aircraft; why some passengers near exits do not survive; how exits or aisles become blocked; how people get trapped and clothing becomes torn; and, the wide range of individual responses to the crowded cabin and competition at the exit. The trials have also highlighted the importance of training for this situation of members of cabin staff, and how the configuration at the exit can influence the extent to which they are able to assist passengers.

Since the volunteers in the trials do not represent a cross-section of the travelling public (no young, elderly, or disabled volunteers are included) it must be argued that in a real emergency, the problems highlighted by these findings could only be worse. The information obtained must be regarded as an initial attempt to collect baseline data.

Future Work

At Cranfield in 1987 and 1988 the first program of research into passenger behavior in aircraft emergency evacuations was conducted. Following this initial study, three further configurations at the exit have been evaluated.

In 1989, it is proposed to extend the program of evacuation trials. At the conclusion of these programs an examination of behavior and exit rates when (a) passengers are in an orderly non-competitive evacuation (b) motivated to compete to egress and (c) in conditions involving a smoke filled cabin, will have been undertaken. The analyses of these evacuations will include the influence of the configuration at the bulkhead and the seating configuration at the Type III exit.

Following a preliminary investigation, a research program into methods for improving presentation of safety information to passengers is being undertaken.

In 1989/1990 it is hoped that, with the acquisition of a cabin mock-up, it will be possible to conduct a study of passenger behavior opening the Type III door. In such an investigation the influence of passenger briefing information, crowding, the size and weight of the door, the seating configuration by the door and the provision of two Type III doors in close proximity could be examined.

An experimental program of evacuation trials will also be developed to examine the effect of the behavior and commands used by cabin staff on passenger behavior in an emergency.

In conclusion, there is obviously a requirement for further investigations into the configurational, environmental, procedural and behavioral factors that can influence human survival in an aircraft emergency. ♦

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Helen Muir is the director of the Applied Psychology Unit in the College of Aeronautics, Cranfield Institute of Technology, U.K. A chartered psychologist, she obtained a degree in psychology from St. Andrews University and a Doctorate from the University of London. She has been involved in human factors research in the field of transportation since 1973.

Since joining the College of Aeronautics in 1984 and establishing the M.S. Course in Applied Psychology, her objective has been to develop and promote research and teaching programs in the field of aviation psychology. Under her direction, expertise in the field of pilot workload assessment and crew activity analysis was developed, and this area is now a significant part of the research and teaching activities of the department. While she continues to maintain an interest in pilot workload assessment, the field of cabin safety and aircraft emergencies is her main area of research interest. This has led to the development of a research facility for cabin evacuation trials and to a major program of research into passenger behavior in aircraft emergencies.

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